

JPRS 79728

24 December 1981

# USSR Report

ENGINEERING AND EQUIPMENT

No. 82

**FBIS**

FOREIGN BROADCAST INFORMATION SERVICE

#### NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [ ] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

#### PROCUREMENT OF PUBLICATIONS

JPRS publications may be ordered from the National Technical Information Service, Springfield, Virginia 22161. In ordering, it is recommended that the JPRS number, title, date and author, if applicable, of publication be cited.

Current JPRS publications are announced in Government Reports Announcements issued semi-monthly by the National Technical Information Service, and are listed in the Monthly Catalog of U.S. Government Publications issued by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Correspondence pertaining to matters other than procurement may be addressed to Joint Publications Research Service, 1000 North Glebe Road, Arlington, Virginia 22201.

# USSR REPORT ENGINEERING AND EQUIPMENT

No. 82

## CONTENTS

### AERONAUTICAL AND SPACE

Parametric Synthesis of Automatic Aircraft Stabilizer.....	1
Estimating Applicability of Hypothesis for Hybrid Design Calculation Procedures.....	1

### NON-NUCLEAR ENERGY

Optimizing Contents of Operating Equipment in Electric Power Plants.....	3
Effect of Conducting Rotor Shells on Some Cryoturbogenerator Characteristics.....	4
Planning and Operating Industrial Water Supply Systems for Large Modern Fossil-Fuel and Nuclear Electric Power Plants.....	4
Elektrotyazhmash Two-Pole 500 MW Turbogenerator Rotor With Water-Cooled Winding.....	5
Simulation and Analysis of Induction Hydrogenerator Modes at Krasnoyarsk Hydroelectric Plant.....	5

### CONSTRUCTION

Hybrid Dirigible Being Developed.....	6
---------------------------------------	---

### INDUSTRIAL TECHNOLOGY

Method of Formalized Representation of Technological Operation in Robotics.....	9
Stability of Controlled Superconductive Suspension.....	9

Development of Mathematical Model Describing Elastic Manipulator on Movable Base.....	10
Effect of Impact on Servomechanism of Manipulator Robot.....	11
Stability of Lightly Loaded Journal in Noncircular Aerodynamic Bearing of Finite Length.....	11
Radial Gas-Static Bearing With Active Gas Flow Regulation by Means of Elastic Compensators.....	12
Optimization of Aerostatic Bearings With Feed Through Slots.....	13
Static Balancing of Mechanical Arm Components.....	13

#### TURBINE AND ENGINE DESIGN

Dynamic Characteristics of Axial Bearing in Turbomachines.....	14
Development and Experimental Evaluation of Diagonal Turbine.....	14
Improving Efficiency of Carburetor Piston Engine.....	15
Diagnosing and Eliminating 'Oil' Vibration in T-250/300-240 Turbine Shafting.....	16

#### NAVIGATION AND GUIDANCE SYSTEMS

Analytical Design of Regulators for Parabolic Systems of Differential Equations With Constraints on State Functions and on Control.....	17
Optimum Angular Velocity of Aircraft Roll.....	17
Synthesis of High-Precision Tracking Systems Insensitive to Friction.....	18
Simulation of Aircraft Collision in Air.....	18
Quasi-Velocity Tracking Orientation System for Nonrigid Satellites.....	19
Active Damping of Nutations of Current-Conducting Gyro Wheel.....	20
Maximum Climbing Altitude of Weather Rocket in Homogeneous Atmosphere and Uniform Gravitational Field.....	20
Optimization of Pitch Gyro Parameters With Aid of Standard Program.....	21

Adaptive Estimation of State of Gyro Stabilizer With Unknown Parameters.....	21
Influence of Control System Parameters on Dynamic Characteristics of Stabilized Platform Suspension.....	22
Discrete Dynamic Model of Laser Gyroscope.....	22
Practical Method of Checking Deviations in Navigation Systems.....	23
Motion Particulars of Gyrocompass With Magnetic Sensing Element Suspension.....	23
Limiting Capabilities of Systems With Gyrocompass Properties.....	24

#### FLUID MECHANICS

Nonlinear Aerodynamic Characteristics of Deformable Wing Flying Near Shield.....	25
State of Stress and Strain of Container Wall Under Hydrodynamic Pulse Load.....	25
Dependence of Aerodynamics of Wing Profiles With Sweepback on Structural Parameters of Flaps.....	26
Convective Heating of Blunt Body in Hypersonic Nonuniform Gas Flow.....	26
Unsteady Supersonic Viscous Flow Around a Short Plate.....	27
Design of Flat and Axisymmetric Nozzles and Channels for Realization of Prescribed Supersonic Stream at Exit Section.....	28
Aerodynamic Characteristics of Stellate Bodies at Mach 3-5.....	28
Convective Instability of Fluid in Zero-Gravity Vibration Field...	29
Supersonic One-Velocity Flow of Multicomponent Fluid Around Solids.....	30
Explosion of Spherical Layer of Charge in Weakly Compressible Fluid.....	30
Motion of Cylindrical Body Through Surface of Compressible Fluid.....	31
Dependence of Air Ionization in Region Perturbed by Hypersonic Cone on Bluntness Radius of Cone Tip.....	31



## MECHANICS OF SOLIDS

Stability Calculation of Thinwall Shell With Regard to Damage.....	33
Deformation of Thin Closed Shell by Load Applied Through Hoop.....	33
Axisymmetric Oscillations of Shell of Revolution Containing Fluid With Small Bubble.....	34
Effect of Nonsquareness of Sheath Panels on Stresses in Conical Wings.....	34
Vibrations and Stability of Toroidal Shell Under Normal Pressure..	35
Empirical Relations for Design of Cylindrical Shells for Stability Beyond Elastic Limit.....	35
Roots of Dispersion Equation for Problem of Gas Vibrations Inside Cylindrical Shell.....	36
Steady-State Temperature Distribution in Thin Annular Disk Making Contact With Cylindrical Shells.....	36
Reducing Load on Bearings of Intermediate Gears in Transmissions..	37
Transverse Vibrations of Membrane With Uniformly Moving Corner Grip.....	37
State of Stress and Strain of Coiled Multilayer Cylindrical Shell With Various Overlaps of Endturns.....	38
Vibrations of Cylindrical Shells Due to Loss of Stability.....	38
Effect of Material Instability in Anisotropic Shells.....	39
Axisymmetric Forced Vibrations of Viscoelastic Cylinder of Finite Length Under Kinematic Excitation.....	39
Models of Numerical Solution of Problems in Dynamics of Shells of Revolution With Filler.....	40
Determination of Critical Parameters of Momentary External Pressure for Spherical Shell.....	40
Oblique Penetration of Solid Body Into Barrier.....	41
Effect of Parametric Regeneration During Nonlinear Three- Dimensional Vibrations.....	41
Seismodynamics of Underground Cylindrical Shell.....	42

## TESTING AND MATERIALS

Using Energy Storing Substances in Automobile Gas Turbine Engines.....	43
Structural Method of Improving Accuracy of Pendulum-Type Compensation Accelerometers.....	43
Additional Error Analysis of Pendulum Compensation Accelerometer Operating in Self-Oscillation Mode.....	44

UDC 629.762.2

PARAMETRIC SYNTHESIS OF AUTOMATIC AIRCRAFT STABILIZER

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 16 Nov 79) pp 69-72

BOGOMOLOV, A. I.

[Abstract] The motion of an aircraft is described by a linearized system of differential equations  $\frac{dx}{dt} = Ax + Bu + Ff$  (where  $x^T = [y^T; z^T; w^T]$  is an n-dimensional

vector of phase coordinates, y is an r-dimensional vector of observable x-vector components, z is an s-dimensional vector of nonobservable x-vector components needed to be known for automatic stabilization, w is a p-dimensional vector of nonobservable x-vector components, u is a q-dimensional vector of control actions, f is a t-dimensional vector of perturbations, and  $n = r + s + p$ ). An automatic aircraft stabilizer with a system of Lewinberger observers is synthesized on the basis of these equations, in accordance with the given structure of the x-vector and corresponding structure of matrices A, B, F. A certain change of variables simplifies the technical realization. Figure 1; references 3 Russian. [35-2415]

UDC 539.4:629.7.02

ESTIMATING APPLICABILITY OF HYPOTHESIS FOR HYBRID DESIGN CALCULATION PROCEDURES

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 7 Feb 79) pp 82-85

LEVASHOV, P. D.

[Abstract] A hybrid design calculation procedure is devised on the basis of a mathematical analysis of the structure to be built. The applicability range of one or another hypothesis for the design is estimated on the basis of the traces of stiffness matrices constructed according to a general theory and the given hypothesis. The validity of this criterion is demonstrated on the complete



displacement vector, the applicability of a hypothesis being equivalent to zero deviations of displacements according to this hypothesis from the true displacements. For simplicity, only deviations orthogonal to the external load and their contribution to the total potential energy are considered. The condition of applicability of the hypothesis is then established in terms of the ratio of spurs of two matrices, the applicability range being determined by the order of these matrices. An illustrative example is the design of a 1 1/2-longeron straight wing on the basis of the hypothesis of an invariable form of cross sections. This hypothesis is found to be either valid or not, depending on the relative stiffness of the ribs. References 3 Russian.

[35-2415]

OPTIMIZING CONTENTS OF OPERATING EQUIPMENT IN ELECTRIC POWER PLANTS

Moscow IZVESTIYA AKADEMII NAUK SSSR: ENERGETIKA I TRANSPORT in Russian No 4, Jul-Aug 81 (manuscript received 22 Dec 80) pp 53-58

FAZYLOV, Kh. F., YULDASHEV, Kh. Yu. and KHAMIDOV, Sh. V., Tashkent

[Abstract] The problem of optimizing the content of equipment in electric power plants reduces to finding the combination of sets which, operating over a given period of time to generate a given amount of electric energy, will do so with the minimum fuel consumption or minimum cost. The corresponding minimizable functional can be simplified, if the startup cost is a linear function of the shutdown time, but it is subject to several constraints imposed by simultaneous starting or stopping of sets and by the load dynamics as well as by the cost of energy resources and by the performance characteristics of the distribution network. An algorithm for solving this many-extremum problem is given that involves first constructing the generalized overall characteristics of per-unit increments for the plants and then, on the basis of these characteristics and the given daily system load curve, optimally distributing the load between plants. Smoothing the generalized plant characteristics reduces the optimization problem from one of whole-number nonlinear programming to one of continuous programming. A typical calculation according to this algorithm is compared with the results obtained with the algorithm now used at the All-Union Scientific Research Institute of Electrical Power Engineering. Written in FORTRAN-4 for an M-4030 digital computer, this new algorithm has been used for optimizing the equipment in one Central Asian Unified Power System with 10 fossil-fuel electric plants. Figures 2, tables 4, references 12 Russian.

[15-2415]

# EFFECT OF CONDUCTING ROTOR SHELLS ON SOME CRYOTURBOGENERATOR CHARACTERISTICS

Kiev TEKHNIЧЕСКАЯ ELEKTRODINAMIKA in Russian No 6, Nov-Dec 80

(manuscript received 4 Jan 80) pp 84-88

TITKO, A. I., Institute of Electrodynamics, UkSSR Academy of Sciences, Kiev

[Abstract] A hypothetical 300 MW cryoturbogenerator with rotor shielding is considered. The effect of conducting rotor shields on the 3-phase short-circuit characteristics is evaluated theoretically by the two-reaction method of calculating transients in electrical machines. The problem reduces to a solution of a system of differential equations for the currents in the equivalent two orthogonal windings. In the model of such a cryoturbogenerator its superconductor excitation winding on the rotor is shielded by two conducting shells of different thicknesses against alternating fluxes induced by currents in the armature winding on the stator. A symmetric short circuit is assumed to occur after idle running. The components of transient currents are calculated on a per-unit basis with typical values of design and performance parameters, including various thicknesses of the shielding shells. Also considered is the case of a generator without special conducting shields, but with the structural steel shells acting as shields under transient and asymmetric operating conditions. Figures 2, tables 3, references 5: 3 Russian, 2 Western.  
[31-2415]

# PLANNING AND OPERATING INDUSTRIAL WATER SUPPLY SYSTEMS FOR LARGE MODERN FOSSIL-FUEL AND NUCLEAR ELECTRIC POWER PLANTS

Moscow ENERGETIK in Russian No 8, Aug 81 pp 6-8

KIKISH, O. V., engineer, Yuzhtekhenenergo

[Abstract] An in-depth analysis is done on the requirements of water supply to large electric generating plants as a basis for improving planning and utilization of these systems in modern nuclear and fossil-fuel facilities. It is shown that the technical and economic characteristics of plant operation can be raised and the level of utilization of the water supply system can be increased by comprehensive studies of the industrial water supply facilities in the power plants and distribution networks, with development and implementation of steps to ensure cleanliness of the circulation lines, the tubes of turbine condensers, cooling towers and circulation pumps, and timely removal of deposits and biological contaminants. Additional funding should be made available for carrying out steps to optimize operation of the water supply equipment where necessary. Inspection, monitoring and supervision are very important to keep water supply equipment in working order. Figure 1.  
[7-6610]

## ELEKTROTYAZHMASH TWO-POLE 500 MW TURBOGENERATOR ROTOR WITH WATER-COOLED WINDING

Kiev TEKHNIЧЕСКАЯ ЭЛЕКТРОДИНАМИКА in Russian No 4, Jul-Aug 81  
(manuscript received 22 May 80) pp 54-62

KIL'DISHEV, V. S., CHEREMISOV, I. Ya. and KARPMAN, D. B., Scientific Research Institute of Elektrotiazhmash Plant, Khar'kov

[Abstract] The authors discuss the problems faced by designers in increasing the unit power of a two-pole turbogenerator with rated shaft speed of 3000 rpm and power factor of 0.85 with respect to selection of the method of cooling the rotor winding to give required technical characteristics of static overload capacity of at least 1.6, permissible continuous-duty overload of up to 550 MW and double forcing of the rotor current for 20 s. Two cooling systems were compared: direct hydrogen cooling with opposed axial blower system, and direct water cooling of the conductors of the rotor winding. The diameter of the rotor core was 1120 mm, and the length of the active section was 6200 mm. The water-cooling system was found to be superior. A detailed explanation is given of design modifications required for implementing the proposed cooling system. The Elektrotiazhmash Plant is now producing 12 rotors for 500 MW turbogenerators, and one for a 1000 MW turbogenerators with water-cooled winding of the proposed design. Figures 7, references 9 Russian.  
[6-6610]

## SIMULATION AND ANALYSIS OF INDUCTION HYDROGENERATOR MODES AT KRASNOYARSK HYDROELECTRIC PLANT

Kiev TEKHNIЧЕСКАЯ ЭЛЕКТРОДИНАМИКА in Russian No 4, Jul-Aug 81  
(manuscript received 20 Feb 80) pp 62-65

GAMM, B. Z., YEFIMENKO, N. N., IVANOV, S. V. and PUSTOVITOVA, L. S., Siberian Scientific Research Institute of Power Engineering

[Abstract] To determine the feasibility of induction operation of hydrogenerators at Krasnoyarsk Hydroelectric Plant, a mathematical model is developed that is in quantitative and qualitative agreement with in situ tests. The model includes the generator, transformer, transmission line and busbars. The synchronous generator is modeled by Gorev-Park equations, the damper system is made up of three equivalent circuits in each of the axes of the machine, the turbine equipped with speed regulator is described by a system of fourth-order differential equations with consideration of constraints. The criterion of adequacy of the model is agreement between the torque-speed characteristics of the synchronous original and the induction model. The proposed model is used to evaluate the permissible generator load on the Krasnoyarsk hydrogenerators in induction operation: 60% of the rated load. Figures 2, references 4 Russian.  
[6-6610]

## CONSTRUCTION

### HYBRID DIRIGIBLES BEING DEVELOPED

Moscow PRAVDA in Russian 19 Sep 81 p 3

[Article by M. Vasin: "New Dirigible on the Horizon?"]

[Excerpts] In the conference hall of the Orgenergostroy -- the All Union Institute on Design and Organization of Power Construction -- the furniture was pushed up against the walls, in front of the stage there was a small desk with a panel on it, while in the center of the wide empty space towered a dirigible. Of course, not a full-scale one, but one that was one-tenth of the natural size.

A new model of an airship is to be tested. Imagine two six-meter cigars made of strong cloth, located one above the other and connected by straps and a membrane of the tail assembly.

The last preparations have been made. V. M. Pugachev, chief of the test department, approaching the desk-panel, at which two staff workers were already seated turned to face the hall:

"We now begin!"

Two propellers under the belly of the dirigible began moving. The cigars floated up to the ceiling...

The miniature dirigible held stationary under the ceiling for several minutes as if glued.

"It hangs," said V. M. Pugachev with satisfaction.

"It hangs well," confirmed all those present with pleasure.

"We'll take on a load," the test manager told the people sitting at the desk.

A lever is moved and the dirigible turned in place and lowered smoothly to a latticed structure on the floor. After a minute, it swung lightly under the keel of the rising dirigible. It became clear that the load was a miniature copy of an electric power transmission pole.



"Connect the ventilation in the hall. Set the dirigible in the air current,"

The cigars sailed to the open doors. "Suspended" across the air current flowing into the door, the dirigible turned to it with its bow and stopped, swinging lightly.

"The wind vane operates excellently. No worse than in the previous model."

"Is it such a great advantage for the dirigible to turn to the wind like the wind vane?" I ask Yu. N. Oreshkin.

"True, for a dirigible it is no advantage. But this is not a dirigible and we do not call it that. We are working on the development of an aircraft for construction installation work. While the main purpose of the dirigible is to transport loads, the main goal of our apparatus is different: it is to insure a deviation of structures being installed of not more than 20 centimeters even at wind velocities reaching 14 meters per second (it is precisely such requirements that are imposed on common cranes). We obtain that, making it possible for our apparatus to "walk" freely in a stream of air around its vertical axis, while the LEP [Electrical power transmission line] pole attached to it by means of a special link -- see? -- remains almost stationary. The coupled cigars implement this problem the best way. Another difference from the traditional dirigible is that the lifting force which is provided by balloons filled with helium just balances the weight of the apparatus itself. The load is lifted by the propellers. This arrangement is a disadvantage for a dirigible and requires more power, but is advantageous from the standpoint of mobility and independence, let us say, from the presence of ballast at the loading point. The 'aerial crane' will be ahead of a helicopter in a number of important indicators. First, it is possible to execute a very precise installation. Second, fuel expenditures are considerably lower -- eight to ten times".

The coupled cigars, rustling their propellers softly, continued to sail around the hall, either flying right below the ceiling, or gliding several centimeters above the floor, surely and easily avoiding obstacles, and again and again hanging immobile at a given point.

"What will this hybrid dirigible, plane and crane be like?"

"Very much like the tested model," replied O. A. Chembrovskiy. "Light, simple and inexpensive. Its cigar-shaped body will be about 50 meters long and 40 meters in diameter. Two light aviation engines will be mounted on its rigid suspension arm. Its load capacity will be 6 to 8 tons. The average distance for transporting structures for electric power transmission lines is 250 kilometers at a speed of about 100 kilometers per hour which is entirely sufficient for the production needs. Several hundred such apparatus will meet the greater part of the requirements in installation equipment in LEP construction, as well as in transporting lumber from the construction zone. As a rule, they will be pilotless. This will make it possible to solve the manpower problem more rapidly -- they will be controlled by pilots who, by reasons of age or health, can no longer fly in the air."

This demonstrates that working with practical workers for practical applications stimulates "Energoaerotrans" staff workers to search for realistic and simple solutions to technical, organizational and other problems. To ease the assimilation of mass production of the apparatus it is planned to utilize mainly products that are produced in series by our industry. Only about 5 to 10 percent of the devices and materials used for the "aerial cranes" will have to be made especially for them.

"In the production of these apparatus, we plan to use existing enterprises in the USSR Minenergo [Ministry of Power and Electrification] and it will not be necessary to create a new plant," continued the professor.

"Oleg Aleksandrovich, is it not too early to think of problems related to the series production of the 'flying cranes'? Isn't it true that there is still no production prototype built as yet?"

"No, not too early. Series production problems must be solved simultaneously with the development of the product itself. Only in that way is it possible to avoid difficulties and delays with the introduction of the product. As far as the production prototype is concerned, due to the help of the ministry, staff workers of our institute and outside specialists, the job has progressed so far that it becomes realistic not only to complete the manufacture of an experimental-production apparatus with a load capacity of 6 to 8 tons next year, but also to start its flying tests."

"The success of these tests will open up the possibility of starting series production of the 6-ton apparatus. They are needed acutely in construction. Also another prospect will open up -- soon it will be possible to start building 30-ton apparatus. The situation is that if a second balloon is "hung" on the 6-ton model (as was done on the present model) and another pair of engines added, the total load capacity will increase to slightly less than 30 tons."

O. A. Chembrovskiy looked at the miniature dirigible again. It was doing its successive maneuver under the hall ceiling, laying a road to the sky to the next generation of its powerful offspring.

2291

CSO: 1861/18

UDC 62-501.72

METHOD OF FORMALIZED REPRESENTATION OF TECHNOLOGICAL OPERATION IN ROBOTICS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 7, Jul 81 (manuscript received 27 Jun 80) pp 153-155

KULESHOV, V. S., doctor of technical sciences, professor, SHVEDOV, V. N.,  
candidate of technical sciences, and PODURAYEV, Yu. V., engineer

[Abstract] Synthesis of the control system for an industrial robot does not require consideration of the entire technological process but only a model of the particular operations performed. All the necessary data can be classified into quantitative and textual ones, the latter pertaining to the sequence of actions. Each technological operation can be subdivided into transitions, passes and stages. Its formal representation in machine words is demonstrated here on the stamping of parts from sheet stock, which involves six operations beginning with pickup of a blank from the pile and ending with deposition of a finished part in the tray. The formalization is then extended to cyclic operation, the description of which includes a logic operator. Such a formalization facilitates computer-aided automatic design of robot control systems with general-purpose components by a standard method. Figures 3, references 4 Russian.  
[9-2415]

UDC 62-501.12

STABILITY OF CONTROLLED SUPERCONDUCTIVE SUSPENSION

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian  
Vol 24, No 8, Aug 81 (manuscript received 11 Nov 80) pp 69-74

VORONKOV, V. S., Gor'kiy State University

[Abstract] Control of a superconductive suspension with a magnetic field is considered as means of regulating the equilibrium position of the suspended object while also increasing the stiffness of the suspension and damping its vibrations. The stability analysis of such an automatic control system is based

on a mathematical description of the open loop by the Lagrange-Maxwell differential equations involving the Lagrange-Maxwell function as well as the Rayleigh dissipation function and the generalized force. The uncontrolled suspension is found to be asymptotically stable, according to its characteristic equation with linearized force characteristics in the vicinity of equilibrium. So must be the closed-loop system with an astatic regulator across the object in series with a servo element. The regulator performance is analyzed by the method of D-partition of the parameters space into regions, in the right-hand half-plane D, with equal numbers of roots of the characteristic equation of the closed system. Figures 4, tables 1, references 3 Russian.  
[13-2415]

UDC 627.51

# DEVELOPMENT OF MATHEMATICAL MODEL DESCRIBING ELASTIC MANIPULATOR ON MOVABLE BASE

Moscow IZVESTIYA AKADEMII NAUK SSSR: TEKHNIЧЕСКАЯ КИБЕРНЕТИКА in Russian No 4, Jul-Aug 81 (manuscript received 9 Feb 81) pp 109-114

RAKHMANOV, Ye. V., STRELKOV, A. N. and SHVEDOV, V. N., Moscow

[Abstract] The equations of dynamics are derived for a "movable base - elastic manipulator - load" system, the manipulator consisting of two short members with negligible deformation and two long members. The mass of the servo element is assumed to be negligible in comparison with the load mass. Altogether one stationary and eight movable systems of coordinates are involved in the analysis. The equations for the load position vector are obtained through successive transformations from one system of coordinates to the next. The equations of forces in the Lagrange form are obtained from the potential strain energy, which subtracted from the kinetic energy gives the Lagrange function, and the differential of total work. These equations are supplemented with the equations of dynamics for all direct-current electric drive motors with separate excitation customarily used in manipulator robots. The complete system of equations serves as the basis of a computer simulation program where they are integrated by the Runge-Kutta method and the resulting system of linear algebraic equations for the accelerations is of only the sixth order with only five matrix transformations. Figure 1; references 8: 6 Russian, 2 Western.  
[14-2415]



## EFFECT OF IMPACT ON SERVOMECHANISM OF MANIPULATOR ROBOT

Moscow IZVESTIYA AKADEMII NAUK SSSR: TEKHNICHESKAYA KIBERNETIKA in Russian  
No 4, Jul-Aug 81 (manuscript received 20 Jun 80) pp 103-108

CHUMENKO, V. N. and YUSHCHENKO, A. S., Moscow

[Abstract] The effect of impact on the dynamics of a manipulator servomechanism is analyzed on the basis of a fundamental vector equation in generalized coordinates that describes this action. The mechanism is treated as an open kinematic system consisting of fifth-class translational and rotational pairs. Assuming ideal kinematic couplings and ideally rigid mechanism elements, external actions are represented as instantaneous impulses of "zero" duration applied to a mechanism element at its center of mass or some other arbitrary given point. The change of manipulator velocities due to impact can be determined from this vector equation, if the velocities before impact as well as the force and moment impulses are known. Two impact modes of particular interest here are impact during pickup of an object not coupled to the manipulator base and collision with an obstacle rigidly coupled to the manipulator base. The general results of this analysis are applied to pickup of a moving object and its transfer to a point with given coordinates by a 2-stage manipulator robot on a movable base with three degrees of freedom. Figures 2, references 2 Russian.

[14-2415]

UDC 533.6.011

## STABILITY OF LIGHTLY LOADED JOURNAL IN NONCIRCULAR AERODYNAMIC BEARING OF FINITE LENGTH

Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 81  
(manuscript received 8 Oct 80, after completion 7 Apr 81) pp 113-119

SHUSTER, V. G., Moscow

[Abstract] The stability of the steady journal position in the lubricant of a slightly eccentric circular or slightly noncircular air bearing is analyzed on the basis of the differential equation of pressure distribution and the integral equation of motion of the journal center. Flow continuity in terms of air mass balance constitutes a mixed boundary condition here. The gap width is assumed to be uniform over the bearing length. The solution to these equations reveals that, in the linear approximation, the stabilizing or destabilizing effect depends on the amplitudes but not on the phases of the harmonic components of the circumferential gap function. Every gap harmonic of order  $k \geq 3$  is characterized by a critical bearing length-to-radius ratio  $L/R$  below which a stabilizing effect will appear at any compressibility number  $N_c$  and above which a destabilizing effect will appear at any compressibility number lower than critical. The critical



bearing ratio  $(L/R)_{cr}$  decreases with increasing  $k$ , while the critical compressibility number  $(N_c)_{cr}$  increases with increasing  $k$  and with increasing  $L/R$ . In short bearings, accordingly, small deviations from circularity improve the stability, a third-harmonic distortion being most preferable. In long bearings, however, a third- or higher-harmonic distortion is preferable only at large compressibility numbers and an elliptical distortion is preferable at small compressibility numbers. To every pair of  $L/R$  and  $N_c$  values, moreover, there corresponds an optimum order of harmonic, i. e., a harmonic which will produce the maximum stabilizing effect and should be designed into the bearing cross section. The results of this analysis are illustrated on a differential air bearing with  $R = 1.6$  cm,  $L = 4.8$  cm,  $c = 10$   $\mu$ m on a shaft rotating at 5000 rad/s under no load. Figures 2, references 3: 1 Russian, 2 Western.  
[10-2415]

UDC 621.9:621.89

# RADIAL GAS-STATIC BEARING WITH ACTIVE GAS FLOW REGULATION BY MEANS OF ELASTIC COMPENSATORS

Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 81  
(manuscript received 30 Jun 80, after completion 9 Feb 81) pp 107-112

KODNYANKO, V. A. and SHATOKHIN, S. N., Krasnoyarsk

[Abstract] A radial gas-static bearing with active gas flow regulation is described which consists of a journal, and inner sleeve with radial drill holes, and an outer sleeve around an annular active space of a certain volume. The holes, spaced uniformly around the circumference in one row or in two rows and containing elastic compensators in the form of rubber washers, terminate into the gap on the journal side as damping nozzles of the ring-diaphragm type and into the active space under the outer sleeve as choking nozzles of the straight-diaphragm type. The dynamic performance of such a bearing is analyzed on the basis of the Reynolds equation of transient flow, assuming the number of compensating washers to be sufficiently large to make the method of equivalent continuous feed lines applicable here. The dynamic pressure and the displacement of the shaft center are calculated accordingly, also the degree of stability, as functions of the bearing compressibility number and the bearing length as well as of the compensator elasticity. The frequency characteristics of such a radial bearing are found to be qualitatively similar to the corresponding frequency characteristics of an axial bearing with active gas flow compensation. Figures 3, references 4: 2 Russian, 2 Western.  
[10-2415]

## OPTIMIZATION OF AEROSTATIC BEARINGS WITH FEED THROUGH SLOTS

Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 81  
(manuscript received 7 Jul 80) pp 100-106

BALASAN'YAN, V. S., Moscow

[Abstract] The advantages of aerostatic bearings with air feed through slots over those with air feed through uniformly spaced small orifices are more uniform pressure distribution along the feed path, ensuring more precise shaft rotation, and lower susceptibility to contamination. Here the optimum pressure distribution along a slot is calculated and the corresponding slot width is determined which will yield the maximum bearing stiffness for given gap dimensions. The analysis is based on the Reynolds equation for the pressure distribution in the gap of a bearing with discrete slots, with the appropriate boundary conditions: even symmetry with respect to the bearing center, flow continuity along the feed path with mass balance of lubricating air, and even-symmetry periodicity around the bearing circumference. The results reveal some very weak dependence of the optimum slot width on the feed pressure. The optimum relative pressure in a slot is found to be somewhat lower than in a bearing with feed through orifices and adiabatic discharge. Figures 2, references 6 Russian.

[10-2415]

UDC 621.80:007.52

## STATIC BALANCING OF MECHANICAL ARM COMPONENTS

Moscow MASHINOVEDENIYE in Russian No 5, Sep-Oct 81  
(manuscript received 20 Nov 80, after completion 4 May 81) pp 47-53

TYVES, L. I. and PURTSELADZE, G. K., Moscow

[Abstract] An algorithm for balancing robot arm components is constructed on the basis of spring action rather than the use of counterweights for relieving the drives of static moments due to the weight of the heaviest members. The design algorithm utilizes the fact that the potential energy of a spring is a harmonic function of the driver position. Two such spring mechanisms are analyzed and synthesized accordingly: one for a mechanical arm consisting of rotational pairs and one which constitutes a slider-crank mechanism. Figures 4, references 6 Russian.

[10-2415]

## TURBINE AND ENGINE DESIGN

UDC 621.438.081

### DYNAMIC CHARACTERISTICS OF AXIAL BEARING IN TURBOMACHINES

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 7, Jul 81 (manuscript received 27 Dec 79) pp 77-79

YUNOSHEV, V. D., candidate of technical sciences, ZHIVOV, G. I., candidate of technical sciences, and YEVSTAF'YEV, V. A., engineer

[Abstract] A dynamic analysis of an axial journal bearing in turbomachines requires three second-order differential equations describing the variation of the thickness of the lubricant film in time. With regulation of the axial thrust added, these equations must be supplemented with the equations of motion for all components of the regulator system. Here the resulting system of higher-order differential equations has been linearized on the basis of experimentally determined transient and frequency responses of such a bearing as a control object, in an open-loop system and in a closed-loop system. Measurements of the lubricant pressure and oscillograms of intentionally induced vibrations indicate that such a bearing can be described by a linear model with a transfer function of the type  $W(p) = k/(Tp + 1)$ , i.e. as a first-order aperiodic element. Compressibility of the lubricant and the finite stiffness of the bearing shoes give rise to an inertia which delays the formation of a lubricant wedge. This delay can be reduced, and semifluid or dry friction can be avoided by maintaining adequate pressure. Figures 3, references 3 Russian. [9-2415]

UDC 621.43.031.3.001.5

### DEVELOPMENT AND EXPERIMENTAL EVALUATION OF DIAGONAL TURBINE

Moscow AVTOMOBIL'NAYA PROMYSHLENNOST' in Russian No 8, Aug 81 pp 10-11

CHUMAKOV, Yu. A., candidate of technical sciences, and SVETLOGORSKIY, L. L., Moscow Institute of Automotive Mechanics

[Abstract] A diagonal turbine in the 150-250 kW range for automotive application has been built and tested at the Chair of Gas Turbine Engines for Transportation,

such a turbine ensuring a better structural stability and a higher internal efficiency than a radial-axial turbine. Its main design features lie in the blading geometry: outside and inside surfaces of the blades shaped as hyperboloids of revolution, lateral surfaces of adjacent blades shaped as hyperbolic paraboloids, entrance angle  $137^\circ$ , and exit angle in fixed ratio to the entrance angle. The wheel design parameters are mean entrance diameter of 110 mm and 0.614 ratio of exit diameter to entrance diameter determining the degree of radiality. The nominal turbine performance parameters are internal efficiency of 74%, and expansion (pressure) ratio of 1.6, gas flow rate of 0.4 kg/s at speed of 65,600 rpm, and reaction ratio of 0.6 determined by aerodynamic drag and centrifugal forces as well as by entrance and exit velocities. The actual performance characteristics as functions of the ratio of tangential to normal velocity components, determined by the angle of attack, were measured and found to be optimal within the 0.6-0.8 range of this ratio. No existing diagonal or radial-axial turbine approaches these performance requirements. Figures 4, tables 1, references 2 Russian.  
[33-2415]

UDC 621.43.018

#### IMPROVING EFFICIENCY OF CARBURETOR PISTON ENGINE

Moscow AVTOMOBIL'NAYA PROMYSHLENNOST' in Russian No 8, Aug 81 pp 7-10

ZAKHAROV, L. A., candidate of technical sciences, RABEKO, V. G., POPOV, A. V., SOKOLOV, S. N. and BUSYGIN, V. Ya., Zavolzhskiy Motor Plant imeni Semicentennial of the USSR

[Abstract] A single-row intake manifold has been developed which is equivalent to two manifolds feeding the fuel mixture from a double-barrel carburetor to four cylinders each of a V-8 engine. It is designed to be more economically producible, by casting, and to operate more efficiently than the existing series-produced double-row manifold. It has been tested separately and with an engine, in the laboratory and on the road. Its performance has been found to be superior with respect to higher fuel efficiency and better combustion characteristics, including lower toxicity of the exhaust gases, to ensure uniform distribution of fuel mixture to all cylinders, and to result in overall weight reduction. An engine with this manifold has also satisfactorily passed all standard starting, running, knocking, and reliability tests. At constant speeds of 60-90 km/h, a standard V-8 engine refitted with this new manifold by proper adjustment of the ignition advance angle burned fuel at the rate of 29 liters per 100 km (8.12 mpg) as compared with 30.4 liters per 100 km (7.75 mpg) when running with conventional equipment. Figures 6, tables 1.  
[33-2415]

DIAGNOSING AND ELIMINATING 'OIL' VIBRATION IN T-250/300-240 TURBINE SHAFTING

Moscow ENERGETIK in Russian No 8, Aug 81 pp 15-17

MIKUNIS, S. I., candidate of technical sciences, Central Repair Plant, Moscow Power System

[Abstract] Foundation strains on some T-250/300-240 turbines result in redistribution of the specific load on some of the bearings. This causes self-excitation of low-frequency vibrations due to the destabilizing action of the oil layer in the bearings. The author discusses the problem of diagnosing these "oil" vibrations by frequency analysis to determine which sections of shafting are affected by load relief on the various bearings, and ways to redistribute loading to eliminate vibrations. Steps are recommended for preventing vibrations of this kind in periodic inspection and maintenance. Figures 4.  
[7-6610]



## NAVIGATION AND GUIDANCE SYSTEMS

UDC 62-50

### ANALYTICAL DESIGN OF REGULATORS FOR PARABOLIC SYSTEMS OF DIFFERENTIAL EQUATIONS WITH CONSTRAINTS ON STATE FUNCTIONS AND ON CONTROL

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 15 Nov 79) pp 105-107

SMIRNOV, S. V.

[Abstract] The analytical design of a regulator for a system describable by parabolic partial differential equations with distributed parameters is carried out under constraints on the functions of state and on the magnitude of the control. Accordingly, an open bounded region in an M-dimensional Euclidean space is defined and all possible controls in the class of piecewise-continuous functions with a finite number of break points are sought which will transfer the system from a given initial state with given boundary conditions to a final state satisfying a given inequality (constraint) within a finite period of time. The problem is reduced to a minimax problem, after the bilateral inequality has been replaced with a unilateral one, and then solved by the method of local optimization requiring successive differentiation of the minimizable function with respect to time until a derivative is found which involves the control function explicitly. References 2 Russian.  
[35-2415]

UDC 629.19

### OPTIMUM ANGULAR VELOCITY OF AIRCRAFT ROLL

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 11 Dec 79) pp 102-104

PRIVARNIKOV, O. A.

[Abstract] The optimum angular velocity of aircraft roll is determined from the condition of minimum total range error within the atmospheric layer, where the gyroscopic effect due to roll opposes the stabilizing effect of the air on

oscillations of the angle of attack but where roll also reduces the dispersion due to a shift of the center of gravity away from the longitudinal axis. Accordingly, the first derivative of the range error is equated to zero and its second derivative made positive. The corresponding equation is solved with the exclusion of hovering modes and is found to yield a rather large optimum roll velocity. References 4 Russian.  
[35-2415]

UDC 62-50:629.783

#### SYNTHESIS OF HIGH-PRECISION TRACKING SYSTEMS INSENSITIVE TO FRICTION

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 22 Jun 79) pp 99-102

UL'TRIVANOV, I. P.

[Abstract] The synthesis of a high-precision system for tracking a star with a telescope mounted on gimbals on board a spacecraft is shown which corrects for the rotation of the spacecraft while the latter moves along its orbit. The system includes a goniometer, a correcting device, a power amplifier and a torque motor. The synthesis involves a computer-aided solution of three transcendental algebraic equations for the three parameters  $A$ ,  $\Delta$ ,  $\omega$  characterizing the oscillation of the steady-state output error signal  $\varepsilon = \Delta + A \sin \omega t$  and all three depending on the dry friction in the system, a solution which will yield a total error  $\delta = A + \Delta$  independent of the friction torque, i. e., a zero derivative of this error with respect to the friction torque - over the range from zero to the critical friction torque, at which all three parameters increase by a jump. Figures 4, references 2 Russian.  
[35-2415]

UDC 621.396

#### SIMULATION OF AIRCRAFT COLLISION IN AIR

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 21 May 79) pp 95-97

SULEYMANOV, N. T.

[Abstract] Collision in air between two aircraft in a single test is simulated according to the Monte Carlo method, assuming that each aircraft moves in a straight line in three-dimensional space at a different constant velocity  $V$  ( $V$  being a random quantity uniformly distributed over the  $\{V_{\min}, V_{\max}\}$  range). The proximity between offensive aircraft and defensive aircraft is checked for danger by minimizing the square of the distance between them, determined from

the equations of motion for each, and comparing that minimum with the square of the critical distance  $d$ . The probability  $P$  of dangerous proximity is then calculated as a function of the initial distance  $R$  between the two aircraft, the Euclidean metric being most convenient to use for this purpose. This probability is  $P = 1$  when  $R = d$  and  $P = 0$  when  $R \rightarrow \infty$ . The algorithm has been programmed for an M-222 digital computer. Numerical data are shown for  $V_{\min} = 400$  km/h,  $V_{\max} = 2600$  km/h,  $d = 4$  km and a trajectory slanting by not more than  $6^\circ$ . Figure 1, references 3 Russian. [35-2415]

UDC 629.7.017.2

#### QUASI-VELOCITY TRACKING ORIENTATION SYSTEM FOR NONRIGID SATELLITES

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 10 Apr 79) pp 91-94

PAVLOV, Yu. N. and SEVEROVA, L. V.

[Abstract] An algorithm of tracking a nonrigid spacecraft with a high-frequency relay-pulse control system is proposed which uses the lower sheet of the phase biplane and follows the method of point transformation, an algorithm easily programmable for a digital computer and much simpler than tracking by determining first the phase trajectory of translatory motion and then the phase trajectory of perturbations. It is based on the equation of motion for a control wheel, taking into account friction and windage torques proportional to the angular velocity. The  $(\theta, \dot{\theta})$  phase plane is subdivided into  $2(n_1 + n_2) + 1$  vertical strips ( $n_k = 1, 2, \dots, n_1$  and  $n_p = 1, 2, \dots, n_2$  denoting the numbers of pulses decreasing the modulus of the velocity in the phase half-planes  $\dot{\theta} > 0$  and  $\dot{\theta} < 0$  respectively) and the increments of velocity from one to the next are determined. Stable closed trajectories are shown to exist in the phase plane, the mapping point in each half-plane moving along a parabolic trajectory segment and all trajectories asymptotically approaching a stable closed isolated limit cycle. An analysis of the equation relating all parameters of the limit cycle yields the system design parameters which, within the range of technical feasibility, will ensure the required limit cycle. It also yields the relation between any two or three variables, with the other parameters held constant or varied in discrete steps. Figures 3, references 4 Russian. [35-2415]

## ACTIVE DAMPING OF NUTATIONS OF CURRENT-CONDUCTING GYRO WHEEL

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 17, No 9, Sep 81  
(manuscript received 5 Mar 79) pp 99-105

KOMAROV, V. N., Scientific Research Institute of Applied Mathematics and  
Cybernetics, Gor'kiy State University

[Abstract] Controlling the nutation of an electrostatic gyro with a spherical wheel is considered, the nutation angle in a rotating magnetic starter field being determined principally by the initial conditions. On the basis of the dimensionless equations of motion in normalized phase variables, including Euler angles, the torque is calculated which results from interaction of the external magnetic field and the eddy currents it induces in the wheel. This nutation damping control torque depends neither on the initial angle nor on the dynamic characteristics of the wheel but on the orientation of its axis of symmetry. The algorithm of active damping of nutation within a finite period of time is shown in two schematic variants where the external magnetic field, parallel to one principal fixed plane through the wheel axis and rotating at some constant angular velocity, is switched every half-period of wheel rotation with a reversal of polarity. The larger this torque is and the earlier it is applied, the faster will the nutation angle decrease. Figures 2, references 6: 5 Russian, 1 Western. [32-2415]

UDC 629.197.2

## MAXIMUM CLIMBING ALTITUDE OF WEATHER ROCKET IN HOMOGENEOUS ATMOSPHERE AND UNIFORM GRAVITATIONAL FIELD

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 1: MATEMATIKA, MEKHANIKA  
in Russian No 5, Sep-Oct 81 (manuscript received 28 Nov 79) pp 70-74

ALEKSANDROV, Yu. I.

[Abstract] The problem of optimizing the motion of a rocket so that it will climb to the maximum possible altitude is formulated as a problem in classical calculus of variations. It is solved by first determining at a fixed initial velocity how the ratio of rocket mass at time  $t$  to initial rocket mass must vary to maximize the altitude and determining this maximum altitude, then determining the initial velocity that will yield the highest maximum altitude. The integrand is linear with respect to the rate of change of rocket mass. The solution covers two cases, with the ratio of aerodynamic drag to initial rocket mass proportional to time and proportional to time squared respectively. Accordingly, the optimum motion combines three modes: motion by inertia, "programmed" motion, and motion at constant velocity. Numerical calculations are shown for a typical rocket under typical conditions in a homogeneous atmosphere and a uniform gravitational field.



The study was made under the guidance of professor V. M. Tikhomirov.  
Figures 2, reference 1 Russian.  
[34-2415]

UDC 531.383

#### OPTIMIZATION OF PITCH GYRO PARAMETERS WITH AID OF STANDARD PROGRAM

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian  
Vol 24, No 8, Aug 81 (manuscript received 7 Jul 79) pp 78-84

SERGEYEV, M. A., YABLONSKAYA, V. A. and KUBENSKIY, A. A., Chair of Control  
Instruments on Board, Leningrad Institute of Precision Mechanics and Optics

[Abstract] A program for optimizing the parameters of a pitch gyro with mixed characteristics of control action is shown. Its basis is the nonlinear equation of motion of the sensing element relative to the outer gimbal axis with an angular momentum, with a corrective torque for roll and yaw of the aircraft, and with a dry-friction torque at the inner gimbal axis which depends on the sign of the pitch velocity. An unknown random function characterizing the angle between the apparent vertical and the principal gyro axis is introduced into this equation, and the latter is solved by the method of statistical linearization with the spectral densities of aircraft yaw, roll and pitch taken into account. The program provides for calculation of the rms error of the pitch gyro as a function of four parameters: angular momentum, corrective torque, dry-friction torque, and initial angular misalignment. For optimization of all four, to yield an rms error not larger than permissible, there are also needed standard programs giving the optimum angular momentum and dry-friction torque. Figures 2, references 6 Russian.  
[13-2415]

UDC 531.383

#### ADAPTIVE ESTIMATION OF STATE OF GYRO STABILIZER WITH UNKNOWN PARAMETERS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian  
Vol 24, No 8, Aug 81 (manuscript received 4 Nov 80) pp 74-78

LEPORSKIY, A. A., Leningrad

[Abstract] The parameters of a gyro stabilizer mounted on a moving object depend on the trajectory of the object and are generally unknown. Here a tri-axial linear gyro stabilizer is considered and its equations of state are derived from the differential equations of its motion. Subsequently an adaptive observer system is synthesized, with the aid of Lyapunov's direct method, for asymptotically estimating the state of the stabilizer from data on its precession angle and on the control voltage of its drive motor. References 3: 2 Russian, 1 Western.  
[13-2415]



## INFLUENCE OF CONTROL SYSTEM PARAMETERS ON DYNAMIC CHARACTERISTICS OF STABILIZED PLATFORM SUSPENSION

Leningrad IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 24, No 3, Mar 81 (manuscript received 14 Jan 80) pp 36-39

KALININA, G. I., Leningrad Institute of Precision Mechanics and Optics

[Abstract] An examination is made of the structure and parameters of a system for stabilizing and orienting a suspension platform that carries measurement equipment on oceangoing vessels. The analysis is based on a mathematical model of the system including the object of control and the mechanisms that ensure rapid damping of natural oscillations of the platform. The model of the object of control is a one-link rigid pendulum. Stabilization is by a positional control system with additional velocity control of the regulated parameter. Stabilization of the platform relative to the horizon is accomplished by inserting asymmetry into the suspension system. The analysis shows that introducing the additional velocity channel upsets the conditions of stability of the control system, and imposes severe constraints on its parameters. Conditions of velocity invariance cannot be satisfied in such systems. Damping of pendulum oscillations requires control of the suspension platform near its center of mass. Figures 3, reference 1 Russian.

[39-6610]

## DISCRETE DYNAMIC MODEL OF LASER GYROSCOPE

Leningrad IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 24, No 3, Mar 81 (manuscript received 25 Mar 80) pp 49-53

YENIN, V. N. and KUZNETSOV, V. F., Moscow Higher Technical Academy  
imeni N. E. Bauman

[Abstract] The use of laser gyroscopes as precision angular velocity sensors requires digital methods of difference frequency measurement. The difference frequency signal is converted to a count pulse sequence by special pulse shaper circuits in which two photocells are used with sensing areas displaced by a  $1/4$ -wavelength to determine the direction of rotation. A laser gyroscope model is proposed in this paper that simplifies analysis of the dynamics of such a system. In this model, the nonlinear phase equation that describes the continuous part of the laser gyroscope is replaced by a linear equation within the limits of a single quantized step of the phase difference, and the pulse component of the gyroscope is represented by a special block diagram. Analysis of this discrete model shows that it describes the properties of laser gyroscopes in statics and dynamics with accuracy adequate for practical purposes, and accounts for the

discrete nature of data extraction from the laser gyroscope. In addition, the approximate model enables substitution of graph-analytical calculation for the computer method. Figures 4, references 7: 6 Russian, 1 Western.  
[39-6610]

UDC 621.372.85

#### PRACTICAL METHOD OF CHECKING DEVIATIONS IN NAVIGATION SYSTEMS

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian  
Vol 24, No 3, Mar 81 (manuscript received 11 Jul 79) pp 53-56

SEMUSHIN, I. V., Ul'yanovsk Polytechnical Institute

[Abstract] A matter of decisive importance in optimum navigational data processing is monitoring of the deviations of system operation (failures of instrument equipment or changes in vehicle parameters). The author considers a new simplified method of keeping track of such deviations based on a damped Schuler loop that is excited by exponentially correlated noise and is described by a 5-dimensional vector of state. The condition of the system is evaluated by a Kalman filter. It is shown that the proposed method is practicable, and can be used to detect changes in the dynamics of the vehicle, in perturbation characteristics and in the measurement channel. Realization is ideal for vehicle guidance systems since only a small volume of digital computer storage is required. Figure 1, references 3 Western.  
[39-6610]

UDC 531.383

#### MOTION PARTICULARS OF CYROCOMPASS WITH MAGNETIC SENSING ELEMENT SUSPENSION

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian  
Vol 24, No 7, Jul 81 (manuscript received 13 Oct 80) pp 70-74

DENISOV, G. G. and POZDEYEV, O. D., Gor'kiy State University  
imeni N. I. Lobachevskiy

[Abstract] A gyrocompass with magnetic suspension of the sensing element differs from the compass with torsion suspension in appreciable attenuation of torquing by using a ferromagnetic ball for suspension and centering. The moments that limit precision of the instrument are due to interaction of the ball with the magnetic field of the suspension, and these moments arise only in the case of simultaneous disruption of symmetry of the field of the suspension and the ball (in the magnetic respect) relative to the vertical. To reduce these moments, the ball is made from a ferromagnetic alloy with low coercive force. Despite precautions, errors in manufacture and internal inhomogeneities give rise to

anisotropic magnetization properties, so that the ball acts as a triaxial ellipsoid with respect to moment interaction. In this paper an analysis is made of the influence that torques in the magnetic suspension have on the readings and on the attenuation of precessional motion of the sensing element in a gingle-rotor gyrocompass. A numerical example is given. Figures 2, references 4 Russian. [5-6610]

UDC 531.383

#### LIMITING CAPABILITIES OF SYSTEMS WITH GYROCOMPASS PROPERTIES

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE  
in Russian Vol 24, No 7, Jul 81 (manuscript received 10 Apr 80) pp 74-80

SLIV, E. I., BORISOV, Yu. A., ZOST, Z. G. and SOL'NITSEV, R. I.,  
Leningrad Institute of Precision Mechanics and Optics

[Abstract] Systems with gyrocompass properties containing gyroscopes, torque sensors, amplifiers, motors, correction indicators, sensors of angles, angular acceleration, and so on are usually analyzed as ideal systems with linear characteristics, constant steady-state parameters, and no internal perturbations, disregarding the dynamics of the stabilization system and the systems for correction of the gyroscopic components. This approach cannot account for limiting capabilities of such systems designed around components with nonlinear characteristics and random errors. In this paper, a technique is proposed for evaluating limiting capabilities of such systems in several stages. The initial stage involves formulation of a generalized model and algorithms for simulating systems with gyrocompass properties on a digital computer with consideration of "nonideality" of system components. The method is described in detail, and a flowchart of an algorithm is given. A numerical example demonstrates the feasibility of the technique for practical evaluation of the limiting capabilities of systems with gyrocompass properties when the characteristics of the system components are known. Figures 2, references 6 Russian. [5-6610]

UDC 533.69

NONLINEAR AERODYNAMIC CHARACTERISTICS OF DEFORMABLE WING FLYING NEAR SHIELD

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 18 May 79) pp 107-111

TSVETKOV, L. G.

[Abstract] Low-velocity subsonic flight of a thin wing with a deformable bearing surface near a shield below is considered, with a sheet of "horseshoe" vortices forming in the wake, assuming slow and small harmonic variations of the kinematic parameters (altitude, pitch angle, yaw angle, roll angle). For a calculation of the nonlinear local and integral aerodynamic characteristics according to the Zhukovskiy formula "in the small", the aerodynamic coefficients as well as the vortex intensity are represented in the form of Taylor series including terms of second-order smallness. References 2 Russian.  
[35-2415]

UDC 532.5+539.319

STATE OF STRESS AND STRAIN OF CONTAINER WALL UNDER HYDRODYNAMIC PULSE LOAD

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 27 Mar 79) pp 97-99

TEN, P. D. and PEREL'MAN, R. G.

[Abstract] An experimental study was made of stresses and strains in the front wall of a container with fluid under hydrodynamic pulse loads produced by solid spherical bodies dropping into it. The container was cubical in shape with edge of 430 mm, its walls made of 2 mm thick D16AT (aluminum alloy) strip and joined along the edges by 45x45 mm steel angle brackets. Balls 9 mm in diameter and weighing 3 g each were dropped into the fluid with an impact velocity of approximately 1800 m/s. Stresses in the front wall were measured with strain-gage resistors made of constantan or manganin, nominal resistance 200  $\Omega$  and gage base 100 mm long, strains were recorded by amplified transducer signals on an N-115 loop



oscillograph. The oscillograms reveal three phases of deformation, each due to a different loading mode and each characterized by a different duration and different stress intensity. First occurs a "splash", then follows cavitation with a subsequent collapse of voids. Figures 3, table 1, references 6 Russian. [35-2415]

UDC 629.735.01

#### DEPENDENCE OF AERODYNAMICS OF WING PROFILES WITH SWEEPBACK ON STRUCTURAL PARAMETERS OF FLAPS

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATIONNAYA TEKHNIKA in Russian No 2, Apr-Jun 81 (manuscript received 12 Oct 78) pp 85-88

MATYAZH, A. I., STERLIN, V. A., POPOV, V. A., ISAYEV, V. V. and CHEREMUKHIN, G. A.

[Abstract] An experimental study was made to determine the effectiveness of flaps used for increasing the lift coefficient of wings with sweepback. Models of two identical rectangular compartments for the tip and for the root were tested with both a flap and an aileron. The two principal parameters of a flap, its angle with and distance from the wing profile chord, were varied one at a time with the other held constant. The three main aerodynamic performance characteristics, lift and drag coefficients and pitching moment, were measured at a Reynolds number  $N_{Re} = 1.01 \cdot 10^6$ . The measure of flap deflection was the flap dihedral angle, its relation to the angle between flap chord and wing chord having been established beforehand. The results of this study indicate that the maximum lift coefficient as well as the critical angle of attack corresponding to burble depend strongly on the flap orientation (a dihedral angle of  $43-44^\circ$  being optimum within the given test range) while at the tip they depend very strongly and at the root they depend hardly at all on the relative distance of the flap distance (a clearance of 2.5-3% being optimum within the same test range). In the testing and the data processing participated also M. A. Kopyrin, V. Ye. Fesenko and L. A. Sadykova, Figures 5, table 1, references 4 Russian. [35-2415]

UDC 536.7:536.24

#### CONVECTIVE HEATING OF BLUNT BODY IN HYPERSONIC NONUNIFORM GAS FLOW

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 81 (manuscript received 10 Dec 79) pp 127-133

YEREMEYTSSEV, I. G. and PILYUGIN, N. N., Moscow

[Abstract] Convective heating of an axisymmetric blunt body by a radially divergent supersonic stream of hot gas is considered in an arrangement where the stream originates from a spherical source with the center at a certain



distance  $L_0$  from the stagnation point on the body. The shock wave leaves behind a region of inviscid flow and generates before it a compression layer. The convective thermal flux at the body surface is determined according to the theory of laminar heat transfer. The equations of gas dynamics are solved after generalized Hugoniot relations have been established for the gas parameters as functions of the radially varying Mach number. In the typical example of a spherical nose streamlined and heated by a nonuniform gas stream the distribution of thermal flux over the body surface is found to be determined principally by the ratio of the distance  $L_0$  to the radius of curvature  $R_0$  at the stagnation point. Figures 5, references 11: 8 Russian, 3 Western. [12-2415]

UDC 633.657.2

# UNSTEADY SUPERSONIC VISCOUS FLOW AROUND A SHORT PLATE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKhanika ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 81 (manuscript received 21 Nov 79) pp 111-118

KAZAKOV, A. V., Moscow

[Abstract] Nonsteady supersonic viscous flow around a plate with a dashboard is analyzed, assuming a Reynolds number  $N_{Re} = \rho_\infty u_\infty L / \mu_\infty = \epsilon^{-2} \rightarrow \infty$  ( $\rho_\infty, \mu_\infty$  - density and dynamic viscosity of the gas,  $u_\infty$  - velocity of the oncoming stream,  $L$  - distance from the front edge of the plate to the hinged dashboard). In a dimensionless system of quantities, each referred to the appropriate characteristic parameter, the length of the dashboard is assumed to be of the order  $N_{Re}^{-3/8}$ , the pressure drop across any one section being of the order of  $N_{Re}^{-1/4}$  and the time in which it swings downstream through an angle of the order of  $N_{Re}^{-1/4}$  also being of the order of  $N_{Re}^{-1/4}$ . The thermal and flow characteristics of the boundary layer within the interaction zone are described in the form of collocating asymptotic expansions and as such inserted into the Navier-Stokes equations of two-dimensional transient flow. With vorticity replacing the longitudinal velocity as one variable, these differential equations are transformed to difference equations of second-order accuracy, according to an implicit scheme with respect to time. These equations are solved by standard numerical methods. On the basis of calculations made according to the given algorithm, the profiles and the transients of pressure, vorticity, and thermal flux (gradient of enthalpy) are found, as well as the lift coefficient and the swing coefficient. The author thanks V. Ya. Neyland for the valuable suggestions. Figures 5, references 14 Russian. [12-2415]

# DESIGN OF FLAT AND AXISYMMETRIC NOZZLES AND CHANNELS FOR REALIZATION OF PRESCRIBED SUPERSONIC STREAM AT EXIT SECTION

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 4, Jul-Aug 81 (manuscript received 25 Dec 79) pp 94-102

KRAYKO, A. N. and SHELOMOVSKIY, V. V., Moscow

[Abstract] An analytical procedure is outlined for designing a flat or annular (axisymmetric) supersonic nozzle or channel. The object is to shape the supersonic outlet stage and to match the subsonic inlet stage so as to realize a supersonic stream with prescribed characteristics at the exit section. These characteristics are the enthalpy and the specific entropy, in the general case nonuniformly distributed, and the twist of the stream. All three characteristics depend on the flow function and on the mode of stream buildup along the nozzle. The problem reduces to a Cauchy problem and auxiliary Goursat problems, which can be solved numerically with the aid of a computer. The gas is assumed to be ideal and the flow is assumed to be shockless. As a typical example the authors consider a nozzle or channel which converts an isentropic stream at the entrance to a nonisentropic supersonic stream at the exit. The authors thank V. A. Vostretsova for the assistance. Figures 5, references 22: 20 Russian, 2 Western.

[12-2415]

# AERODYNAMIC CHARACTERISTICS OF STELLATE BODIES AT MACH 3-5

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 4, Jul-Aug 81 (manuscript received 31 Jan 80) pp 88-93

VEDERNIKOV, Yu. A., GONOR, A. L., ZUBIN, M. A. and OSTAPENKO, N. A., Institute of Mechanics, Moscow State University, Moscow-Novosibirsk

[Abstract] An experimental study was done to determine the aerodynamic characteristics of stellate bodies at Mach numbers 3, 4 and 5. All test models had the same length  $L = 65$  mm and midspan cross-sectional area  $S_M$ , but various ratios  $r^0 = r/R$  ( $r$ -distance from axis to inner rib at the midspan,  $R = 25$  mm radius of equivalent circular cone) and various numbers of lobes  $n$ . They were grouped into three series: with  $r^0 = 0.4$  and  $n = 3, 4, 6, 8$ ; with  $r^0 = 0.6$  and  $n = 3, 4, 6, 8, 10, 15$ ; with  $r^0 = 0.8$  and  $n = 3, 4, 6, 8$ . Also measured were the aerodynamic characteristics of solids of revolution with power-law generatrices ( $m = 0.65-0.8$  at the midspan), having the same overall length and cross-sectional area at the midspan as the stellate models. The angle of attack  $\alpha$  was varied from  $-2$  to  $15^\circ$ . A numerical and graphical evaluation of the data yields the drag coefficient  $C_x$  and the lift coefficient  $C_y$  as functions of  $N_{Ma}$ ,  $\alpha$  and  $n$ . The

total drag coefficient can, furthermore, be split into its four components  $C_x^b$  (wave drag),  $C_c$  (countercurrent drag),  $C_T$  (skin-friction drag) and  $C_g$  (ground drag). The experimental data agree with theoretical calculations only in the lower range, where flow conditions approximate those of a plane shock wave attached to front edges. A discrepancy appears in the higher range, where calculations do not account for internal shock waves with attending large compression regions which tend to separate the boundary layer after the shock wave has separated and been replaced by a density jump attached below the plane of front edges. The results on the dependence of the aerodynamic characteristics on the ratio  $r^0 = r/R$  were not sufficient at any of the three different Mach numbers to indicate at what ratio  $r^0$  the drag becomes minimum. Figures 5, references 12: 10 Russian, 2 Western.  
[12-2415]

UDC 532.5.013.4:536.25

#### CONVECTIVE INSTABILITY OF FLUID IN ZERO-GRAVITY VIBRATION FIELD

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKhanika ZHIDKOSTI I GAZA in Russian No 4, Jul-Aug 81 (manuscript received 3 Mar 80) pp 12-19

GERSHUNI, G. A. and ZHUKHOVITSKIY, Ye. M., Perm'

[Abstract] A cavity with a given temperature distribution at the boundary is filled with a mechanically incompressible fluid and vibrates harmonically along a fixed axis under conditions of zero gravity. An analysis of the secondary flow due to the driving force is made, in the high-frequency case, on the basis of vector equations of flow derived from the complete equations of convection by the method of averaging. The conditions of mechanical equilibrium, i.e., absence of average flow are determined according to the method of small perturbations, with linearization and reduction of the three-dimensional problem to a two-dimensional one. The temperature distribution at the cavity boundary is first assumed to produce a constant temperature gradient parallel to the axis of vibration, in which case the conditions of equilibrium can be satisfied by a cavity of any shape. With the temperature gradient oriented arbitrarily, however, equilibrium is possible only in special configurations. Such cases are: a plane layer of fluid between two parallel infinitely large solid plates with a normal temperature gradient and an arbitrarily oriented axis of vibration, a layer of fluid between two coaxial circular infinitely long cylinders with a radial temperature gradient and an axis of vibration coinciding with the common axis of these cylinders, and a layer of fluid inside a hollow circular infinitely long cylinder with a radial temperature gradient and an orthogonal radially oriented axis of vibration. The stability limits and the critical Rayleigh number for each case have been calculated by numerical integration according to the Runge-Kutta method. The authors thank G. I. Petrov for the helpful discussion. Figures 3, references 9: 8 Russian, 1 Western.  
[12-2415]

## SUPERSONIC ONE-VELOCITY FLOW OF MULTICOMPONENT FLUID AROUND SOLIDS

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 1: MATEMATIKA, MEKHANIKA  
in Russian No 5, Sep-Oct 81 (manuscript received 13 Jun 80) pp 85-88

RAZMATULIN, Kh. A. and SMANOV, T.

[Abstract] The authors analyze supersonic flow of a multicomponent fluid around a solid, assuming the flow to be supersonic everywhere and that the components of the medium do not move relative to one another. The fundamental mass and volume relations between components are established for the general case of  $n$  components, taking into account the concentration of each. A special case is that of a 2-component medium consisting of an incompressible fluid and a compressible one, air saturated with fine dust or water saturated with gas bubbles being the most typical examples. The equations of mass, energy and momentum conservation are solved for a thin body with a sharp tip or edge at which an attached density jump will occur. Mapping the solution from the physical plane of flow onto the hodograph plane yields the shock polar, from which both the lift coefficient and the drag coefficient can be calculated. References 4 Russian. [34-2415]

UDC 536.24

## EXPLOSION OF SPHERICAL LAYER OF CHARGE IN WEAKLY COMPRESSIBLE FLUID

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 1: MATEMATIKA MEKHANIKA  
in Russian No 5, Sep-Oct 81 (manuscript received 28 May 80) pp 74-78

SAGOMONYAN, Ye. A.

[Abstract] Explosion of a charge filling the space between two concentric spherical surfaces in a boundless fluid medium is analyzed, the fluid being weakly compressible so that only a small change of density occurs under a pressure buildup and the acoustic approximation ceases to be applicable. Two spherical shock waves are generated, one convergent and one divergent. It is assumed that the explosion products do not mix with the ambient fluid and that the buildup of gas pressure along the propagation path is a polytropic process. The corresponding equations of motion and continuity in a system with spherical symmetry are solved for each wave, with the  $\frac{1}{\rho} \frac{\partial \rho}{\partial t}$  term in the continuity equation

assumed to be negligible in comparison with the two other  $\frac{\partial v}{\partial r}$  and  $\frac{2v}{r}$  terms ( $\rho$  - density,  $v$  - velocity,  $r$  - radial coordinate,  $t$  - time). The fluid is assumed to be describable by the same equation of state for the shock-wave region and the continuous-flow region, the flow being potential and conforming to the



Cauchy-Lagrange integral. The velocity profiles along both waves and the pressure distribution in the fluid have been calculated for specific initial conditions by the Runge-Kutta method of numerical integration. Calculations were done by Ya. P. Dvorkin. Figure 1, table 1, references 2 Russian. [34-2415]

UDC 533.6.013.49

#### MOTION OF CYLINDRICAL BODY THROUGH SURFACE OF COMPRESSIBLE FLUID

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 8, Aug 81 (manuscript received 23 Sep 80) pp 42-47

KUBENKO, V. D., Institute of Mechanics, UkSSR Academy of Sciences

[Abstract] A straight horizontal circular cylinder is considered falling on the surface of an ideal compressible fluid occupying the half-space below. The motion of this cylinder through the initial stage of immersion, during which the boundary conditions still correspond to those of an unperturbed fluid surface, is described analytically together with the variation of the hydrodynamic pressure on its surface during that period. The velocity of the cylinder at the instant of touchdown is given. The problem reduces to an integral equation of motion for a solid body interacting with a fluid and a differential equation of wave motion for a fluid. This boundary-value problem is solved, in the approximation of small immersion depths, with either the velocity or the dynamic pressure distributed over the surface in the form of a Fourier series. A numerical solution has been obtained by the Runge-Kutta method for the example of a cylinder immersing in a fluid while the acoustic waves have not yet crossed the fluid surface and the pressure remains proportional to the velocity. Figures 2, references 17: 15 Russian, 2 Western. [16-2415]

UDC 532.526

#### DEPENDENCE OF AIR IONIZATION IN REGION PERTURBED BY HYPERSONIC CONE ON BLUNTNES RADIUS OF CONE TIP

Novosibirsk ZHURNAL PRIKLADNOY MEKHANIKI I TEKHNICHESKOY FIZIKI in Russian No 4, Jul-Aug 81 (manuscript received 10 Jun 80) pp 12-16

BIKART, E. M., LADNOVA, L. A., POLYANSKIY, A. F., SKURIN, L. I. and YURKOV, A. V., Leningrad

[Abstract] A cone with a blunt tip is considered moving through air at a hypersonic velocity. Earlier theoretical data on profiles of the temperature and the



electron concentration, revealing the effects of mass transfer and physico-chemical processes on the plasma formation around the lateral surface of spherically blunted cones, are used here for analyzing the dependence of air ionization within the flow field on the bluntness radius of the cone tip. These data had been obtained by a global method of calculation, assuming a zero angle of attack and a Reynolds number  $N_{Re,\infty} \gg 3000$  referred to the bluntness radius. The results of the analysis indicate that, as the bluntness radius becomes larger, the degree of ionization in the near zone increases but the electron concentration in the far zone decreases sharply. The effects due to nonmonotonic distribution of plasma characteristics such as the electron concentration are more pronounced when the cone flies at high altitudes, where the flow of the ambient medium is laminar. There the temperature distribution around an only slightly blunted cone becomes nonmonotonic, with a "plateau" between its rising range and its dropping range, but remains monotonic in the wake of such a cone. Figures 5, references 7: 6 Russian, 1 Western.  
[11-2415]

UDC 624.074.4:539.3

STABILITY CALCULATION OF THINWALL SHELL WITH REGARD TO DAMAGE

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 12 Jun 78) pp 77-79

ZAYCHIK, V. S. and KALINICHENKO, V. G.

[Abstract] The state of stress of a smooth circular cylindrical shell under axial compression is considered in the case where such a shell has several surface defects generally of different sizes and at arbitrary location. The calculations are based on finite discrete area elements in a cross section. They reveal which defects interact with one another, and which can be regarded as isolated. The calculations have been programmed in ALGOL-60 for a Minsk-22 computer. The results are useful for analysis of local stability and in design of thin-walled fuselages. Figures 2, references 4 Russian.  
[35-2415]

UDC 539.3:629.7.02

DEFORMATION OF THIN CLOSED SHELL BY LOAD APPLIED THROUGH HOOP

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 10 Oct 78) pp 66-69

ANTUF'YEV, B. A.

[Abstract] The contact problem of deformation under a symmetric cyclic load is solved for a thin closed shell of revolution with a positive Gaussian curvature and with a hoop of uniform cross section and stiffness covering an arc of a great circle. The load acts on the shell through this hoop in the plane of the latter. The state of stress and strain is described by linear equations according to the theory of shells. The solution, namely the deflection functions, is sought in the form of trigonometric series, with the condition of compatibility for shell and hoop displacements satisfied approximately according to the Bubnov-Galerkin method. Numerical data are shown for a spherical shell with a

hoop of square cross section around the entire great circle without eccentricity, with eight concentrated normal forces acting on the hoop at points  $45^\circ$  apart. Figures 4, table 1, references 6 Russian.  
[35-2415]

UDC 533.6.013.42

AXISYMMETRIC OSCILLATIONS OF SHELL OF REVOLUTION CONTAINING FLUID WITH SMALL BUBBLE

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 1 Aug 78) pp 60-65

SHKLYARCHUK, F. N.

[Abstract] An elastic shell of revolution is considered which serves as a tank containing an ideal compressible fluid, not to full capacity, with a small gas bubble inside along the vertical axis of symmetry, and which hangs down on hinge supports. The bubble constitutes a source of perturbations, but its surface is assumed to be very small. First the natural vibration modes of such a shell are determined, then its forced longitudinal vibrations due to a movement of the suspension device or due to a vertically acting force. The analysis is based on Lagrange's variational principle, with the effect of gravity disregarded. As a special and limiting case the author considers a hemispherical shell filled to capacity with incompressible fluid, with and without a gas bubble inside. Figures 2, table 1, references 4 Russian.  
[35-2415]

UDC 539.4:629.7.02

EFFECT OF NONSQUARENESS OF SHEATH PANELS ON STRESSES IN CONICAL WINGS

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNIKA  
in Russian No 2, Apr-Jun 81 (manuscript received 19 Nov 79) pp 22-27

VAKHITOV, M. B. and KONYUKHOVA, L. M.

[Abstract] The effect of additional normal stresses due to shearing of non-square sheath panels on the overall state of stress of conical wings has not been analyzed before. Here it is evaluated for a wing of any arbitrary taper, aspect ratio and sweepback. Calculations are based on the model of a longitudinally continuous and transversely discrete stress field. The differential-difference equations of displacements and the equations of force balance for  $j$  infinitesimally narrow panels are solved, with the aid of integrating matrices, for the appropriate boundary conditions and in accordance with Hooke's law. Figures 4, references 9: 8 Russian, 1 Western.  
[35-2415]

## VIBRATIONS AND STABILITY OF TOROIDAL SHELL UNDER NORMAL PRESSURE

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNKA  
in Russian No 2, Apr-Jun 81 (manuscript received 23 Mar 79) pp 18-22

BULYGIN, A. V.

[Abstract] A toroidal shell under normal pressure is considered and its vibrations are analyzed which occur on the inside, near its doubly asymptotic polar axis, namely low-variability longitudinal vibrations and high-variability transverse vibrations. Both series of vibrations are similar to corresponding ones of a cylindrical shell and are characterized by superlow frequencies. The frequencies of each series and the stability limits are calculated here from the solution to the respective eigenvalue problem and the corresponding displacement integral, taking into account the symmetry as well as the appropriate boundary conditions. Numerical results obtained on the basis of this theory agree with experimental data within 20% at the lowest frequencies over a wide range of pressures. The third series of vibrations, due to the existence of a negative-curvature zone on the torus surface, is not considered here. Figures 2, references 6: 5 Russian, 1 Western.

[35-2415]

UDC 539.374

## EMPIRICAL RELATIONS FOR DESIGN OF CYLINDRICAL SHELLS FOR STABILITY BEYOND ELASTIC LIMIT

Kazan' IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: AVIATSIONNAYA TEKHNKA  
in Russian No 2, Apr-Jun 81 (manuscript received 14 Jan 80) pp 8-13

ANDREYEV, L. V. and KHELOVSKIY, L. T.

[Abstract] Empirical relations are shown suitable for the design of cylindrical shells for stability beyond the elastic limit, without requiring the stress-strain diagram for a given material, under axial compression or under external radial pressure or under a combination of both. These relations yield essentially the critical stress in each case. They have been checked out against experimental data on steel, aluminum and copper shells in the inelastic range. Figures 3, references 15: 10 Russian, 5 Western.

[35-2415]

## ROOTS OF DISPERSION EQUATION FOR PROBLEM OF GAS VIBRATIONS INSIDE CYLINDRICAL SHELL

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 7, Jul 81 (manuscript received 16 Apr 80) pp 56-61

GUZHAS, D. R., candidate of technical sciences, acting docent

[Abstract] In order to evaluate the noise generated by a centrifugal compressor in a gas pipeline, it is necessary to consider all normal waves emanating from it. The dispersion equation describing these waves and relating the vibrations of the gas as well as of the pipeline wall to the sound pressure is derived here for a pressure inside the pipeline  $P_1 = P_{10} J_0(\mu_1 r) e^{j\gamma z}$  and a sound field outside the pipeline  $P_2 = P_{20} H_0^{(1)}(\mu_2 r) e^{j\gamma z}$  ( $J_0$  - zeroth-order Bessel function,  $H_0^{(1)}$  - zeroth-order Hankel function,  $r$  - radial coordinate,  $z$  - longitudinal coordinate,  $\mu_1^2 + \gamma^2 = \omega^2/c_1^2$ ,  $\mu_2^2 + \gamma^2 = \omega^2/c_2^2$ ,  $\omega$  - frequency of vibrations,  $c$  - velocity of sound). This equation has one purely imaginary root which corresponds to an "almost" plane wave inside a cylindrical shell with an elastic impedance and to a plane wave inside a shell with a rigid wall. It has one purely real root of small absolute magnitude which corresponds to an "almost" plane wave inside a cylindrical shell with an inertial impedance. The other roots of this equation are real. Figure 1, references 2 Russian.  
[9-2415]

## STEADY-STATE TEMPERATURE DISTRIBUTION IN THIN ANNULAR DISK MAKING CONTACT WITH CYLINDRICAL SHELLS

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian  
No 7, Jul 81 (manuscript received 12 Dec 79) pp 53-56

GORSKIY, N. L., candidate of technical sciences

[Abstract] An axisymmetric system is considered which consists of a thin annular disk in contact with one cylindrical shell outside and another cylindrical shell inside, convective heat transfer taking place at the lateral surfaces of both cylinders as well as at both faces of the disk. The thickness of each cylindrical shell can be different on both sides of the disk, but the thermo-physical properties of all materials as well as the heat transfer coefficients are assumed to remain constant. The steady-state temperature distribution along the radius of the disk and along the generatrices of the cylinders is calculated, assuming an ideal contact throughout and disregarding any radiative heat transfer. The analysis is based on the differential equation of heat transmission through a circular annulus, which is reduced to a system of linear algebraic equations for the most general case. One special case is that of a disk insulated inside,



without an inner cylinder. The results are applied to a typical example of a pipe inside a coaxial sheath with a diaphragm between them. Figures 3, references 3 Russian.  
[9-2415]

UDC 621.833

#### REDUCING LOAD ON BEARINGS OF INTERMEDIATE GEARS IN TRANSMISSIONS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 7, Jul 81 (manuscript received 10 Dec 79) pp 29-31

GRINKEVICH, V. K., doctor of technical sciences, RUDNITSKIY, V. N., candidate of technical sciences, and SUSANIN, V. I., candidate of technical sciences

[Abstract] The static load on bearings of intermediate gears in transmissions is equal to twice the tangential force. It can be reduced if the angle between its line of action and that of the normal pressure force on the meshing gear teeth is made larger. This requires proper positioning of the intermediate gear or gears relative to the centerline between the driver gear and the driven gear. Here the design is shown, in the case of one intermediate gear and in the case of two intermediate gears, on the basis of a theoretical analysis of the overall geometry. A typical numerical example is given. Figures 3, references 1 Russian.  
[9-2415]

UDC 534.12

#### TRANSVERSE VIBRATIONS OF MEMBRANE WITH UNIFORMLY MOVING CORNER GRIP

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 17, No 9, Sep 81  
(manuscript received 8 Sep 80) pp 127-130

BORISOV, B. P., Gor'kiy Polytechnic Institute, and VESNITSKIY, A. I., Gor'kiy State University

[Abstract] An exact solution is obtained to the problem of transverse vibrations of an infinitely large membrane with a uniformly moving corner grip. The corresponding wave equation without perturbations but with a moving boundary and constraints at infinity yields the displacement of such a membrane. The natural transverse modes are calculated by the method of asymptotic expansions for Bessel functions, first at low velocities and then at high velocities of the boundary. As the velocity of the boundary approaches the velocity of transverse waves, multiple reflections of plane waves can no longer occur and the original equation becomes an ill-conditioned one. Experimental data suggest that shock waves are generated then. Figures 2, references 7 Russian.  
[32-2415]

## STATE OF STRESS AND STRAIN OF COILED MULTILAYER CYLINDRICAL SHELL WITH VARIOUS OVERLAPS OF ENDTURNS

Kiev PRIKLADNAYA MEKhanika in Russian Vol 17, No 9, Sep 81  
(manuscript received 7 Jul 80) pp 122-124

LOBKOVA, N. A., Institute of Mechanics, UkSSR Academy of Sciences

[Abstract] A sheet rolled up into a multilayer cylindrical shell with rigid locking of both inside and outside edges is considered under internal pressure. The state of stress and strain of such a shell is calculated, assuming the shell to be infinitely long and taking into account slippage of turns with sliding friction. On the basis of relations between characteristic angles, an equation is derived for the critical range of the friction coefficient  $f$  depending on the number of layers  $n$  and on the angle of overlap  $\alpha$  of endturns. The minimum friction coefficient is  $f_{\min} = \frac{\log 2}{2\pi} 0.110$  and the maximum friction coefficient in

the specific case of  $n = 5$  layers is  $f_{\max} = 0.372/\alpha$ . Calculations for this case reveal that a change of the overlap angle from 0.072 to 0.290 will not significantly affect the forces in the layers and that, therefore, one cannot appreciably reduce the maximum forces in the layers by increasing the overlap of endturns. Figures 3, table 1, references 2 Russian.

[32-2415]

## VIBRATIONS OF CYLINDRICAL SHELLS DUE TO LOSS OF STABILITY

Kiev PRIKLADNAYA MEKhanika in Russian Vol 17, No 9, Sep 81  
(manuscript received 2 Jul 80) pp 119-122

SIVAK, E. F., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] An experimental study was made of vibrations of cylindrical shells due to local and general loss of stability under axial compression. Two sets of shells made of AMg-6M aluminum alloy were tested: one set of eight (radius  $R = 3.8$  cm, length  $L = 12.5$  cm, wall thickness  $h = 0.005$  cm). Measurements by the resonance method were made with a standard D14 accelerometer on a flexible mounting, VEDS-10A vibration test equipment including a preamplifier for the accelerometer, a "Jupiter-Quadro" amplifier, a galvanometer, and a K12-22 magnetoelectric oscillograph. The shells were excited by an electromagnet to determine their natural frequencies and then axially compressed by a load increasing up to approximately 60% of the critical level with respect to general loss of stability. The maximum deflection amplitudes were later calculated, according to a simple theoretical relation, from frequency and acceleration readings. Figures 4, references 7: 4 Russian, 3 Western.

[32-2415]

## EFFECT OF MATERIAL INSTABILITY IN ANISOTROPIC SHELLS

Kiev PRIKLADNAYA MEKhanika in Russian Vol 17, No 9, Sep 81  
(manuscript received 12 May 80) pp 115-118

SEMENYUK, N. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Anisotropic shells made of composite or laminate materials are considered and the nonlinear theory of such shells is refined so as to account for failure due to instability of the material. The model is an orthotropic homogeneous shell with reinforcing fibers laid along the lines of principal curvatures on some surface. Longitudinal strains and twist angles of the median surface as well as angles of rotation of a normal are assumed to be smaller than unity. From the general relations for strains and displacements, based on the Timoshenko hypothesis, the author derives the equations of equilibrium under external pressure. The critical load for a cylindrical shell is calculated for a material losing its stability in shear. References 9 Russian.  
[32-2415]

## AXISYMMETRIC FORCED VIBRATIONS OF VISCOELASTIC CYLINDER OF FINITE LENGTH UNDER KINEMATIC EXCITATION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 17, No 9, Sep 81  
(manuscript received 7 Jul 80) pp 111-115

SENCHENKOV, I. K. and GUMENYUK, B. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] An exact solution is obtained to the problem of steady-state axisymmetric forced vibrations of a viscoelastic solid cylinder. The cylinder is of finite length, with given displacements at the ends and with no load on the lateral surface. The system of Lamé equations for this cylinder is based on harmonic deformation at some given frequency, with the cylinder material characterized by a complex modulus of shear and a complex Poisson ratio. The problem is solved by the superposition method, with the principle of elastic-viscous-elastic analogy formally extended to linear viscoelasticity. The complex dynamic stiffness, evaluated numerically for a rubber cylinder in a typical situation, is found to remain finite at resonances (local maxima) and not to drop to zero at antiresonances (local minima). Figures 2, references 6: 5 Russian, 1 Western.  
[32-2415]

# MODELS OF NUMERICAL SOLUTION OF PROBLEMS IN DYNAMICS OF SHELLS OF REVOLUTION WITH FILLER

Kiev PRIKLADNAYA MEKhanika in Russian Vol 17, No 9, Sep 81  
(manuscript received 3 May 79) pp 52-56

LYUKSHIN, B. A. and POTEYKO, V. G., Scientific Research Institute of Applied Mathematics and Mechanics, Tomsk State University

[Abstract] Various models are analyzed and compared which serve as a basis of numerical evaluation, with the aid of a digital computer, of stresses and strains in shells of revolution with a filler. For this purpose, the differential equations of motion for cylindrical shells under axisymmetric deformation, with transverse shear and rotational inertia taken into account, are combined with the differential equations of motion for the filler and the boundary conditions are stipulated appropriately, while zero-value initial conditions are assumed for both shell and filler. Algorithms for calculating the reactions and the deflections of such a shell with a filler loaded by body forces, a pulse load being a special case, are given for a two-dimensional model and a one-dimensional model respectively. Both models can be further simplified by the assumption of a quasi-static lightweight filler. The simplified one-dimensional dynamic model is found to be adequate for shells of revolution with a filler, if the state of the latter does not have to be determined with high accuracy. Figures 2, references 6: 5 Russian, 1 Western.

[32-2415]

# DETERMINATION OF CRITICAL PARAMETERS OF MOMENTARY EXTERNAL PRESSURE FOR SPHERICAL SHELL

Kiev PRIKLADNAYA MEKhanika in Russian Vol 17, No 9, Sep 81  
(manuscript received 2 Jun 80) pp 34-38

AMIRO, I. Ya., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] A spherical shell is considered under a momentary external pressure which produces in it a zero-moment state of stress with uniform distribution of compressive stresses varying in time. The problem of dynamic stability is solved, assuming that the shell is shallow within the boundaries of the depression, for three modes of stress variation: 1) compressive stress increasing from zero linearly with time, 2) step change of compressive stress from an initial level to zero, 3) compressive stress decreasing from an initial level linearly with time. The critical load parameters for such a shell in these three modes are evaluated comparatively in terms of the dimensionless pressure action time and the dimensionless pressure pulse magnitude. The results confirm that a step pulse is



most dangerous, its critical action time being relatively the shortest.  
Figures 1, references 8 Russian.  
[32-2415]

UDC 532.58

#### OBLIQUE PENETRATION OF SOLID BODY INTO BARRIER

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA 1: MATEMATIKA, MEKHANIKA  
in Russian No 5, Sep-Oct 81 (manuscript received 9 Jun 80) pp 78-82

SAGOMONYAN, A. Ya. and FILIMONOV, V. A.

[Abstract] Penetration of an obliquely incident small perfectly rigid solid body into a large deformable compressible barrier of finite or semiinfinite thickness is analyzed, assuming that perturbations in the barrier generate acoustic or shock waves while propagating through it. The mechanical characteristics of the barrier material are known and the stresses at the body surface are determined by a known law at every instant of time during the penetration process. The method of analysis is based on numerical solution of the integrodifferential equations of translational motion with rotation under forces acting on the body surfaces. It is applied here to a wedge striking the ground, the latter being regarded as a plastically compressible homogeneous medium. Calculations yield the trajectories, indicating the possibility of ricochet under certain conditions, and the trend of the velocity with increasing depth of penetration. Figures 3, references 4 Russian.

[34-2415]

UDC 539.30/32

#### EFFECT OF PARAMETRIC REGENERATION DURING NONLINEAR THREE-DIMENSIONAL VIBRATIONS

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I  
TEKHNICHESKIYE NAUKI in Russian No 8, Aug 81 (manuscript received 19 Aug 80)  
pp 48-51

PETRENKO, V. Ye. and PAVLOVSKIY, M. A., Kiev Polytechnic Institute

[Abstract] Excitation of resonant vibrations of a mechanical system with viscous damping during its simultaneous nonlinear vibrations in two directions, at the same frequency, is analyzed with the effect of hysteresis friction taken into account. The excitation frequency is assumed to be close to the natural frequency of the mechanical system in the direction where no external force acts, its natural frequency in the other direction being appreciably different. The corresponding equations of motion describe the translational vibrations of a rotor in ball bearings. Their solution, obtained by the method of averaging,



yields the dependence of the maximum resonant amplitude on the excitation level. The results show compensation of viscous friction by the nonlinear interaction of both vibration modes. This effect becomes stronger with increasing nonlinear interaction, with a decreasing hysteresis loop, and with a decreasing ratio of exciting vibroacceleration in the direction of no external force to that in the other direction. These conclusions have been confirmed experimentally in tests with gyro motors. Figure 1, references 5 Russian. [16-2415]

UDC 622.011.4:622.023

#### SEISMODYNAMICS OF UNDERGROUND CYLINDRICAL SHELL

Tashkent IZVESTIYA AKADEMII NAUK UZBEKSKOY SSR: SERIYA TEKHNICHESKIKH NAUK  
in Russian No 3, May-Jun 81 (manuscript received 27 Mar 80) pp 44-48

RASHIDOV, T. and SAGDIYEV, Kh., Institute of Mechanics and Earthquakeproofing  
Equipment imeni M. T. Urazbayev, UzSSR Academy of Sciences

[Abstract] Seismic vibrations of an underground cylindrical shell are analyzed according to the model of viscoelastic friction. The shell is assumed to be thin and made of an elastic material. It makes a solid contact with the ambient medium over its entire surface so that an additional force acts on it that is due to displacement of its median surface and is proportional to the components of the displacement vector. The parameters of free vibrations are determined from the corresponding equations of motion. The effect of interaction and inertia forces on the frequencies of natural vibrations has been evaluated on the basis of a numerical solution, with the aid of a BESM-6 high speed computer, for a cylindrical shell freely supported in an elastic ground. The results reveal that the lowest natural frequency corresponds to the first-order longitudinal vibration mode, that interaction forces, including tangential ones, tend to raise the natural frequencies while tangential inertia forces tend to lower them, and that the lowest frequency of natural transverse vibrations cannot always be determined according to the conventional formula. Figures 2, references 5 Russian. [17-2415]

## TESTING AND MATERIALS

UDC 621.438-66:629.113.4

### USING ENERGY STORING SUBSTANCES IN AUTOMOBILE GAS TURBINE ENGINES

Moscow AVTOMOBIL'NAYA PROMYSHLENNOST' in Russian No 8, Aug 81 pp 11-12

ROD'KIN, K. P., Moscow Institute of Automotive Mechanics

[Abstract] Under consideration as synthetic automobile fuels are so-called energy storing substances, certain chemical elements or their alloys and composites recoverable from abundant oxides with the aid of otherwise wasted energy (heat). The simplest ones are silicon recoverable from sand, in a coal or nuclear heat plant, and aluminum. Most convenient for practical use are Si-Al-Mg composites, inexpensive and nontoxic. Existing automobile gas turbine engines can be converted for operation with such a fuel, its oxidation being possible with either water or air. In the first case the plant includes a fuel tank, water tank, evaporator, economizer, hydrogen generating reactor, combustion chamber, air compressor, heat exchanger, condenser, radiator, and oxide collector. In the second case the plant includes only a fuel tank, combustion chamber, air compressor, heat exchanger, oxide separator, and oxide collector. The performance of an automobile gas turbine engine operating with solid fuel in either of the two variants compares favorably with that of a gas turbine engine and of a Diesel engine operating with conventional liquid fuel. Figures 2, table 1. [33-2415]

UDC 623.4:531.383(024)

### STRUCTURAL METHOD OF IMPROVING ACCURACY OF PENDULUM-TYPE COMPENSATION ACCELEROMETERS

Leningrad IZVESTIYA UCHEBNYKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 24, No 3, Mar 81 (manuscript received 30 Oct 79) pp 60-63

[Abstract] A method is proposed for improving the accuracy of pendulum compensation accelerometers based on regulation with respect to an error signal, bringing the working point of the measuring system to a linear segment of the characteristic response curve, and using astatic balancing to achieve stabilization. Experimental

studies of the given technique on a variety of accelerometers show that the total error for different types of angle-data transmitters is reduced by 10-15%. Conditions are found for minimizing the dependence of the accelerometer output signal on the selection of the working point and its dynamic stabilization. The method is applicable to measurement converters of both electric and non-electric signals. Figures 2, references 7 Russian.  
[39-6610]

UDC 531.768

ADDITIONAL ERROR ANALYSIS OF PENDULUM COMPENSATION ACCELEROMETER OPERATING IN SELF-OSCILLATION MODE

Leningrad IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: PRIBOROSTROYENIYE in Russian Vol 24, No 7, Jul 81 (manuscript received 23 Jun 80) pp 81-86

SKALON, A. I., Leningrad Institute of Aviation Instrument Making

[Abstract] The most extensively used compensation accelerometer systems at present are those with pulse-duration modulation of the output signal in which digital information is formed by special electronic devices for time-pulse transformation of the input signal. The self-oscillatory mode of operation in such instruments is a more natural method of achieving pulse-duration modulation of the output signal since the center of the waveforms is displaced in the presence of an input action, resulting in a time-asymmetric output signal. The self-oscillatory mode can be achieved by introducing a nonlinear link into the regulatory system of the accelerometer with relay static characteristic. This type of system has not been used in pendulum accelerometers because of additional errors that arise due to periodic change in the position of the axis of sensitivity of the device. The author analyzes the conditions that minimize the error components due to displacement of the center of oscillations, and to periodic change in the position of the axis of sensitivity in the plane perpendicular to the axis of the suspension and passing through the arm of the pendulum. Figures 2, references 4 Russian.  
[5-6610]

CSO: 1861

- END -

**END OF**

**FICHE**

**DATE FILMED**

DEC 31-81